E. Spencer
M. Kubantsev
D. Lander
08/04/05

Comparison of Methods of Bump Bonded Modules Diagnostics

At present we have three methods of diagnostics of bump bonded pixel modules.
First, the bump bonded modules delivered from vendor can be X-rayed with a scanning machine available at Feynman Center of Fermilab.
Second, the bump bonded modules mounted on VHDIs and on test boards are tested using electronic tuning procedure developed at the ETHZ showing missing bump channels.
Third, the mounted bump bonded modules are irradiated with radioactive source and looking at hit patterns one can find missing bump (insensitive) pixels.

These methods were applied to recently delivered batch of RTI bump bonded modules with PSI46v2 Read Out Chips (ROC). We concentrated on one module RTI_2x4 #2 X-rayed at the corners as shown on Fig.1

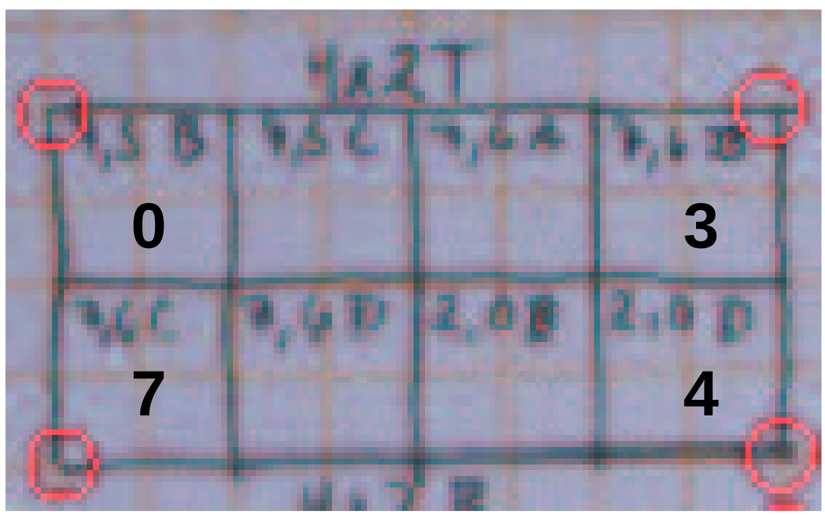
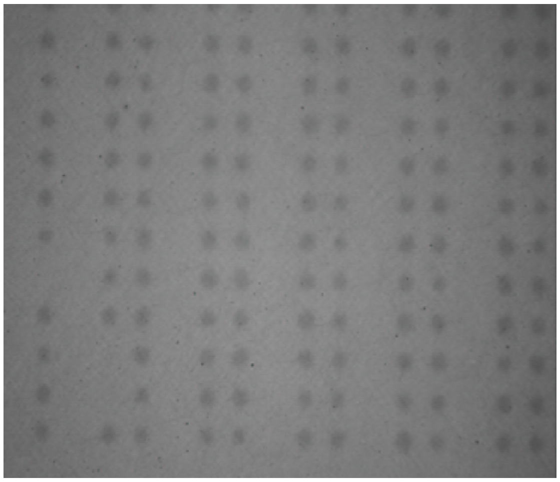
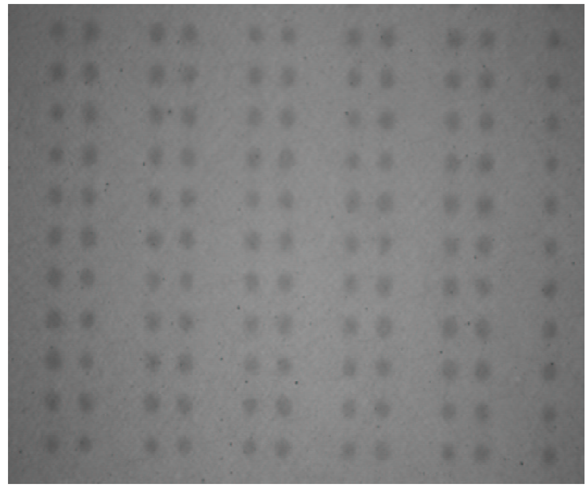


Fig. 1 A scheme of the bump bonded device under test. Areas of X-ray scanned corners are shown. The numbers 0-7 are showing the readout chip positions on the VHDI test board. Indexes 7,5B 7,5C and so on are showing ROC ID. These ID are used to check individual ROC test data.

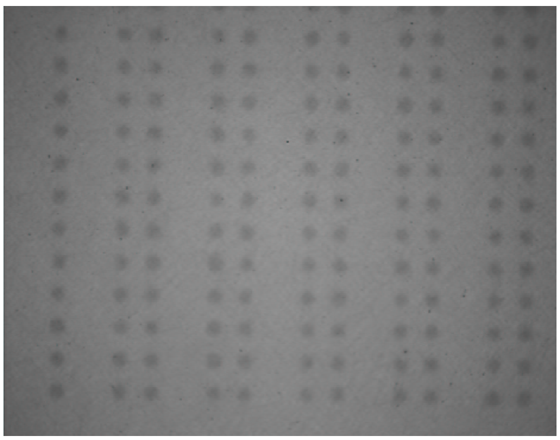
The X-ray pictures are shown in Fig 2 for four corners scanned. One of four corners scanned has three missed bumps on it, and others are apparently good. Note that from previous studies we know that the possible defects of bump bonding are concentrated on the periphery of the module: edges and corners.



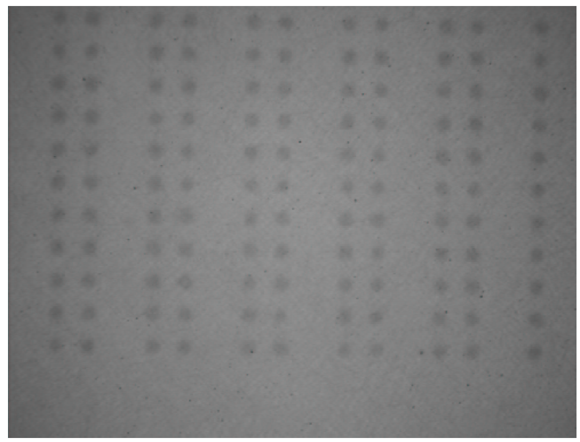
ROC 0 (7,5B)



ROC 3(7,6B)



ROC 4 (2,0D)

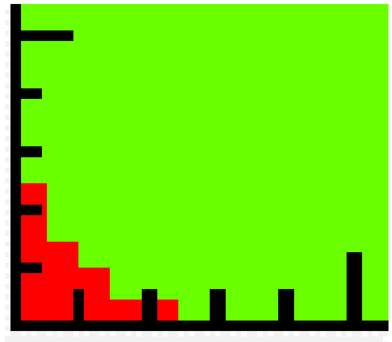


ROC 7 (7,6C)

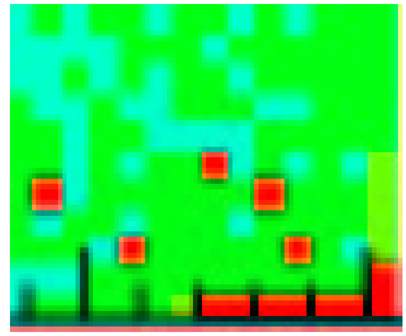
Fig.2 X-ray images of the corners of the chip. Missed bonds are evident on the ROC0

Electronic test of bump bonded modules was developed at the ETHZ (Test D described in U. Langenegger et al, PSI Pixel Meeting, 27.05.2005). The idea is to see response of the ROC pixel preamplifier to leakage current of the sensor. When the amplifier is set to the highest sensitivity, the leakage current saturates it if the amplifier input is connected to the sensor. To the opposite, if the amplifier input is connected with the open ("bad") bond it will be not saturated. This method was verified at PSI and now we are cross checking it. The measurements were made at sensor bias voltage of –250V. The results are shown in Fig 3 for four corners of four X-rayed chips. Red colored pixels are diagnosed as "bad". Comparing with X-ray pictures we see that there are much more "bad" pixels than missing bump bonds in Fig. 1. Note, on the ROC 0 having 3 missing bonds are positioned in agreement with observations of "bad" bonds with the Test D. Other chips have no missing bumps on X-ray image nonetheless we found several missed bonds during electrical test on the chip 3.
Further verification of the procedure was made using a radioactive source. In Fig. 4 results of the radioactive source irradiation (number of hits in each pixel) are shown together with results of the Test D for full area of ROCs 0 and 3. Comparing these results, we see that there is general agreement between the electronic and the source tests; i.e., the three bumps missing on the X-ray photo are also missing with the

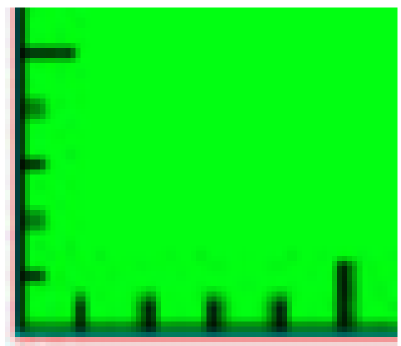
source test. However, not all of the "missed pixels found in electronic test D give no signal with the radioactive source. Many of them do show signals, but with a very low counting rate (low efficiency) compared to their neighbors.



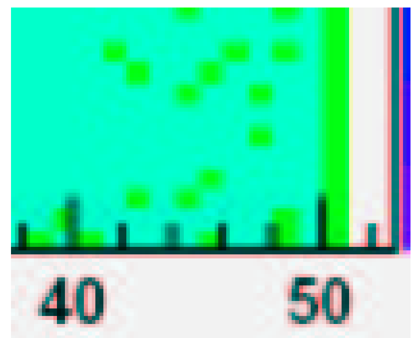
ROC 0 (7,5B)



ROC 3(7,6B)



ROC 4 (2,0D)



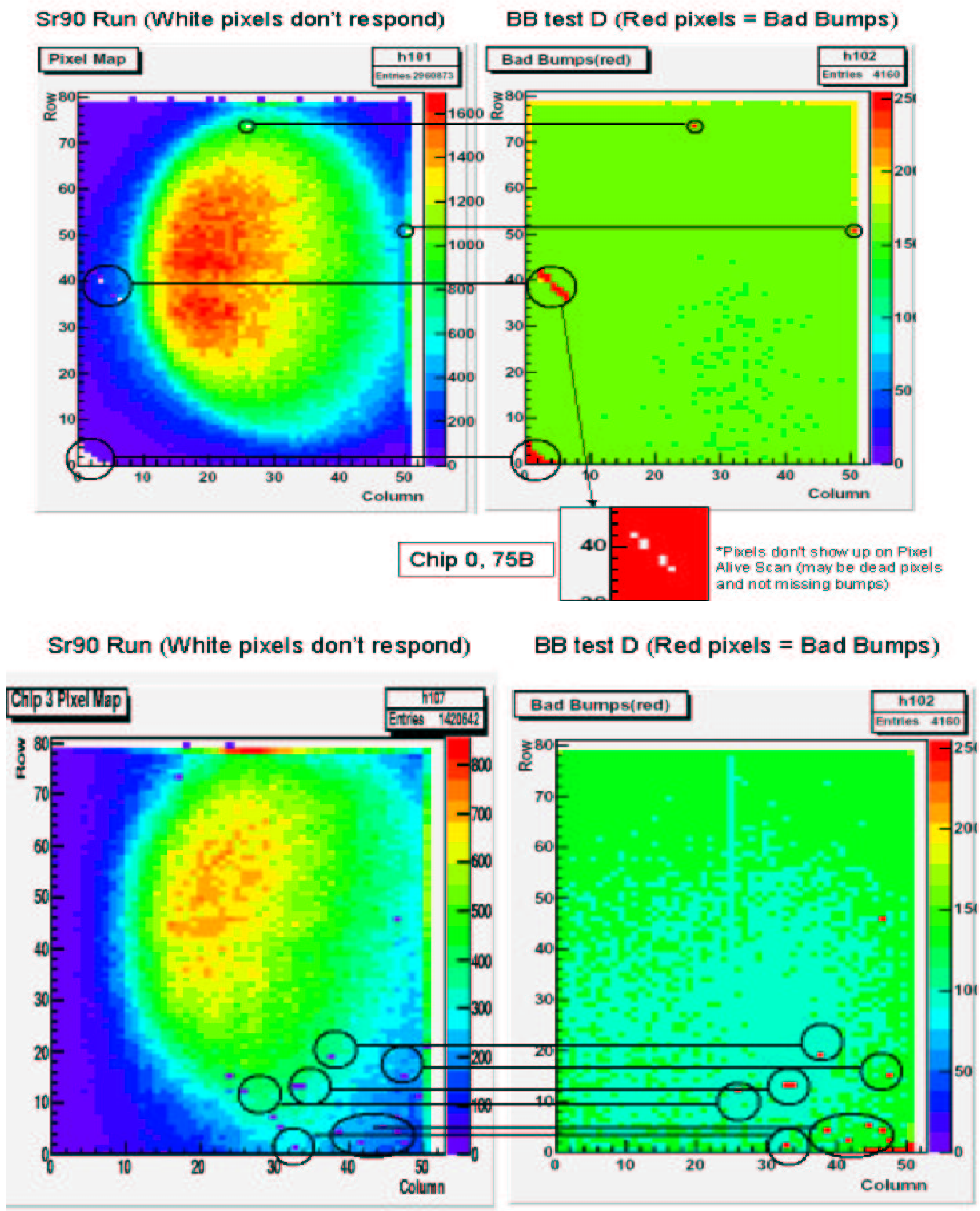
ROC 7 (7,6C)

Fig. 3 Results of the Test D for X-ray-ed corners of the ROCs. ROC 0 and ROC 3 have much more bad bonds that it is seen at X-ray images. ROC 4 and 7 has no bad bonds.

Test D says that there is no direct current contact between the bump and sensor("cold solder") but only a small capacitance. Perhaps a transient pulse at the sensor pad may sometimes induce a signal at the preamp by capacitive coupling across the "open" bump. Another possibility is the counts result from some cross talk between pixels. Neighbor hits can be generated by big depositions of charge on the active pixels.

A more enigmatic situation is found in the comparison shown in the inset of Fig. 4, chip 0. There are 6 pixels (white squares) that were found to be inoperative during “alive” pixel functionality test after bonding before the “missing” bond test D was made. These failures have nothing to do with the bump bonds; the failures must be in the pixel preamplifier or charge injection system itself. Yet after being bonded to a sensor, some of them exhibit signals under irradiation (again with low efficiency), as can be seen in Fig. 4, where the corresponding pixels are not all white (inoperative). It might point to the cross talk contribution discussed above.
From test data from individual ROC testing we know that all bare ROCs we have looked at, have 0 or 1 of bad pixels (grade AA). It is verified for chips under study using the “alive” pixel test and except the chip 0 (7,5B) where a few “dead” channels

were found above, we may account observed “bad” channels as bump bonding defects.



ROC 3(7,6B)

Fig. 4 Full image of ROC 0 and 3 pixel with radioactive source and the electronics Test D. Correlation between two tests is evident.

Overall the quality of the bonding is good. Out of two bump bonded chips fully tested we found 20 (16) “missed” bonds on the ROC 0 with electronics (radioactive) scan and 20 (12) “missed” bonds on the ROC 3. It is about 0.5% of all channels.

In conclusion, the X-ray scan is found to be not an efficient and reliable way to characterize the quality of the bump bonded devices. The electronic test D, developed by ETHZ gives the most reliable and conservative picture of the missed bond channels and takes minimal time, about 10 minutes. The radioactive source exposure test produces similar but incomplete results possibly due to “cold solder” bumps and cross talk in the chip.